RECON NEWS

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BOLT AND OTHER THREAD FAILURES

HOW TO CELEBRATE 30 YEARS?

By doing what we do well. For this issue we were tempted to focus on our history, since much has happened to us and in the accident reconstruction field since David Pesuit, Ph.D., armed with engineering degrees from Lehigh and Yale and corporate engineering experience, hung out his shingle on November 10th, 1977.

But we decided instead to focus on areas where we've made recent contributions. The thread failure case in this issue is a good example, since it shows some clear encounters with junk science developed by experts short on test results and long on points of view.

Next year we will publish correlations that improve the overall accuracy of the tire friction factors reconstructionists use to estimate vehicle speeds. We will also write about propane leaks and fires, using a number of cases in our files.

Contributions aside, we must admit to being proud of our record. We are independent analysts working for plaintiffs and defendants, with a strong belief in the ability of tests to buttress testimony and the power of images over words. On the back page of this issue we include a list of some of our more interesting past newsletters. Copies are available at our website: *accidentanalysisgroup.com*

Martin Schnall and David Pesuit

THE MINNEAPOLIS BRIDGE COLLAPSE

Mechanical failures come in all shapes and sizes. Since this bridge survived for 30+ years, it is obvious to us that its strength degraded substantially before the failure occurred.

Bolted systems like the ones in this newsletter are designed with fourfold safety factors. But some parts are designed with much higher safety factors because they can fail in fatigue at a small fraction of their ultimate strength. We plan to review the reports that will follow this disaster, with an eye toward distinguishing between lack of maintenance on one hand and poor engineering design on the other. So stay tuned . . . .

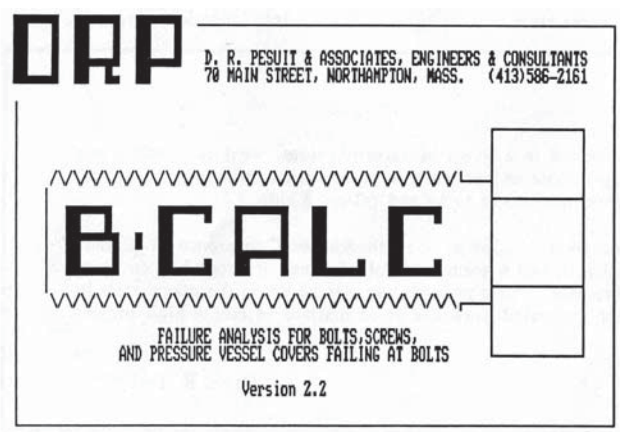
MANY THANKS

Many thanks to attorney Charles E. Gilbert III of Gilbert & Greif in Bangor, Maine who stayed the course on the thread failure case as an obvious manufacturing defect turned into a duel of opposing experts. We are pleased to say that he reached a satisfactory settlement just before trial.

A LONG WINDING THREAD FAILURE YARN

Some of you know that we have been reconstructing failures of threaded connections for more than 25 years. We started out with exploding manhole covers, but soon branched out to include gunnite cement spray equipment and spray painting devices.

Early on, we worked with Bill Heronemus, then Professor of Mechanical Engineering at the University of Massachusetts, to build B-CALC, a computer model that predicts failure pressure for threaded connections using basic information including bolt size and number, metal strength and thread wear.



B-CALC thread strength program from the 1980's

Most of our thread failure cases have been fairly straight-forward. But in a recent case in Maine, we watched with wonderment as an obvious manufacturing defect turned into a battle with opposing experts using bogus theories and misquoted science that we had to counter every step of the way.

THE MANUFACTURING DEFECT

It all started when a high-pressure pipe connection in a large rock crushing machine failed, causing a length of pipe to swing out and seriously injure a worker standing nearby (Exhibit 1).

Exhibit 1 – The rock crusher.

Closeup of the area of failure.


Exhibit 2 – Supply pipe and manifold assembly.

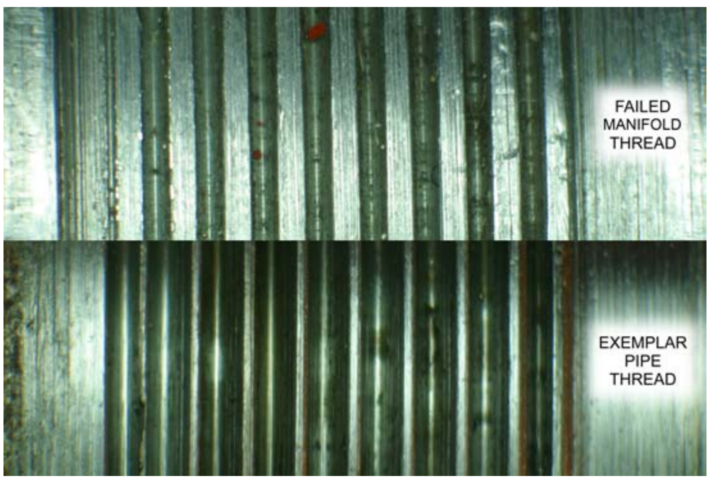


Exhibit 3 – The threads viewed top down.

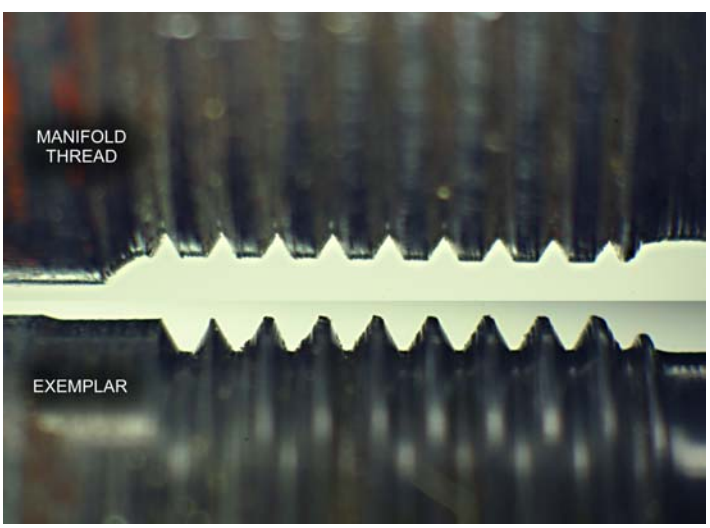


Exhibit 4 – The threads viewed in profile.

Just before the accident, the piping manifold above this supply pipe had been replaced, and workers had aligned and tightened the supply pipe. A hydraulic pump was being used to pressurize the system, and pressure was being monitored because a valve had to be shut off at 2,500 – 2,600 pounds per square inch (psi). One of the workers had just looked at a gauge and saw that the pressure was 2,500 psi when the men heard a loud bang and saw oil come flying out.

Exhibit 2 shows the supply pipe, the manifold section to which its top elbow was attached, and the method of attachment. A ferrule or collar was threaded onto the end of the manifold pipe to provide a stop for the large threaded nut used to secure the supply pipe to the manifold pipe. When this connection failed, the ferrule pulled off the manifold, and the supply pipe rotated forward.

We studied this failure by comparing the failed connection with an identical connection at the bottom of the supply pipe that did not fail. Exhibit 3 shows two edge-on photos comparing the failed manifold pipe threads with the pipe threads at the bottom end of the supply pipe. Exhibit 4 shows two side-on photos comparing these same threads.

It was obvious to us that the tops of the new manifold pipe's threads were *not* sheared off as the ferrule came off the manifold pipe. The manifold pipe threads showed no plowing along their axis; they were sharp edged, and circumferential machining marks were still visible on their tops. Exhibit 5 shows that during manufacture the diameters of both pipe ends were reduced before they were threaded to accept the ferrules, but that much more metal was cut away from the surface of the new manifold pipe. We hypothesized that the ferrule pulled off the new manifold pipe because it had much less thread to grab.

We checked our hypothesis by calculating the strength of the failed connection using the same equations we had developed for the B-CALC model in the 1980's, in which the pressure force pulling the connection apart was just balanced at failure by the shear force bulldozing the ferrule threads. With only about 29% of the ferrule threads damaged, the calculated failure pressure was almost exactly 2,500 psi.

The same calculation for the undamaged threads in the like connection at the bottom of the supply pipe gave a failure pressure of 8,500 psi, almost 3.5 times greater than the 2,500 psi system operating pressure. A 4:1 safety factor has been common in mechanical engineering hydraulic design practice since World War II.

Therefore, we were certain this accident happened because the new manifold section was incorrectly made. Too much of the metal near the end of the manifold pipe had been removed to reduce its outside diameter before the pipe was threaded to receive the ferrule. The resulting pipe threads were truncated. This error created the situation where the manifold's pipe threads met the ferrule threads near their tips where they were weaker. The pipe threads bulldozed through the ferrule threads, allowing the ferrule to slide off and let go.

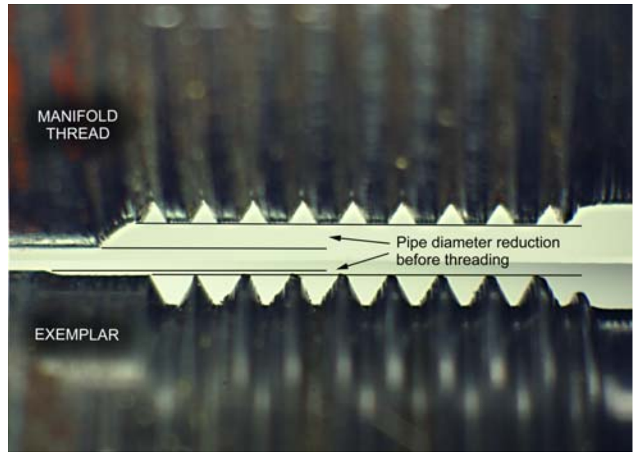


Exhibit 5 – The manifold pipe was turned down too much before threading for the ferrule.

THE FIRST DEFENSE

Although the above analysis was solid and fully documented, we expected resistance. But we were surprised by the bogus analyses that followed over the next two years.

An engineer employee of the manufacturer focused on a small dent in the elbow at the top of the supply pipe (See Exhibit 6), saying that this dent, post manufacture, prevented the nut from tightening fully against the ferrule and allowed hydraulic oil to escape and pressurize the annular cavity of the sealing nut (See Exhibit 7), increasing the force pulling the joint apart and causing it to fail. He provided no evidence that hydraulic oil had entered this annulus, and no calculations to support his position. And he refused to acknowledge that the flattened threads were a manufacturing defect, even though the marks on the tops of the threads were circumferential, not axial.

We used the evidence to refute his position. We produced photos like Exhibit 6, clearly showing that the seal between the ferrule and the elbow was not affected by the dent.

And we used the elbow geometry in Exhibit 7 to refute his position. If hydraulic oil did leak into

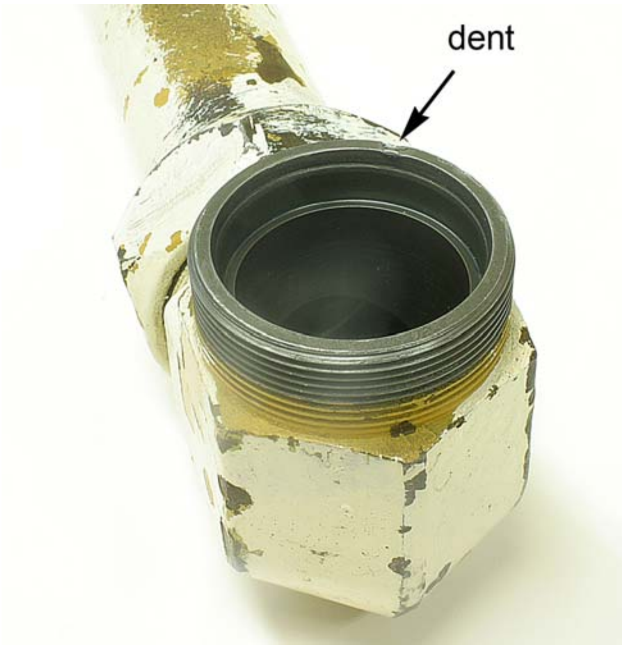


Exhibit 6 – The dent in the elbow and seating area.

this annulus, the greatest additional axial force it could create was the ratio of the increased areas since force is the product of pressure and cross-sectional area. The maximum diameter of the annulus was 2.51 inches; the inside diameter of the elbow 2.02 inches. Therefore, the maximum fractional increase in axial force due to such a leak was the square of the diameter ratio:

$$\text{Fractional axial force increase} = [\text{cavity maximum diameter / elbow diameter}]^2 = [\,2.51 \text{ inches} \,/\, 2.02 \text{ inches}\,]^2 = 1.54$$

which is a 54% increase. But industry codes and the 8,500 psi calculation above showed that this hydraulic system was designed with a 4-fold safety factor. Therefore, there was no way that a 54% increase in internal axial force would make the system fail.

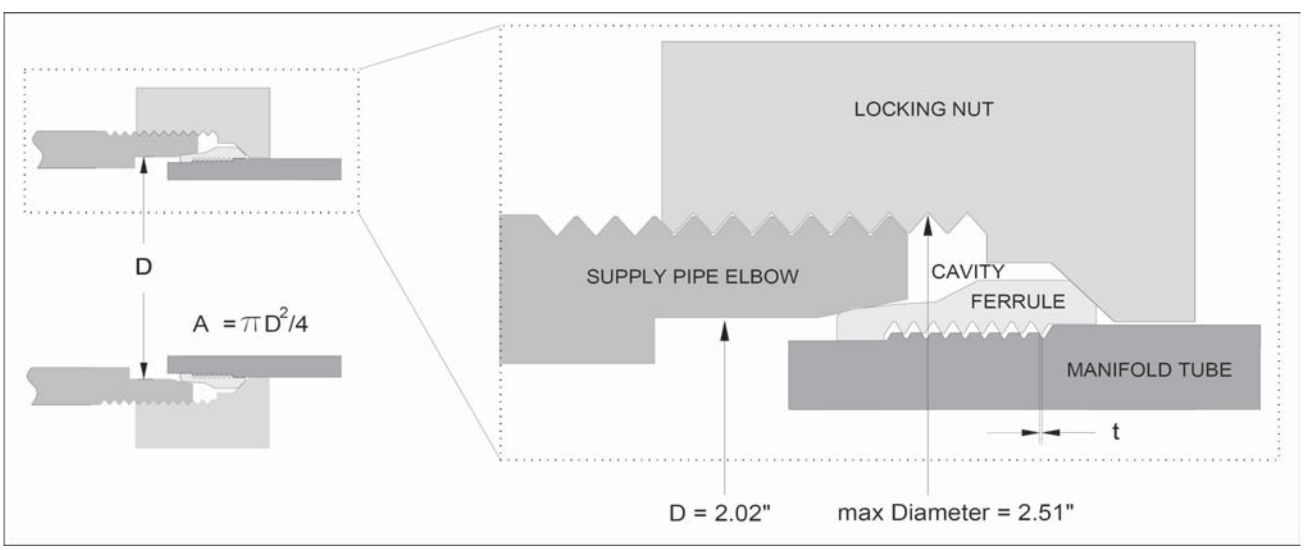


Exhibit 7 – Scale drawing of the threaded joint.

THE SECOND DEFENSE

A PhD engineer hired as an expert witness by the defense also focused on the dent in the elbow, but he came up with an entirely different theory. He said the dent distorted the ferrule, allowing it to slip over the manifold pipe threads and make the joint fail. We placed the ferrule in the elbow without the manifold pipe and tightened the lock nut over it (See Exhibit 9), then measured the inside diameter of the ferrule at many places and found no distortion; the ferrule actually shrank. Therefore, the ferrule would have gripped the pipe threads even more tightly as the elbow nut was tightened, not slipped over them as this engineer had opined.

This engineer also suggested that the ferrule could dilate due to the forces generated by the ramping of its threads as axial forces generated by internal pressure pulled the joint apart. But reference to the literature shows that the dilation he spoke of is only valid for unconstrained nuts. In this case, the ferrule was constrained by the extremely thick backing nut (See Exhibits 6 & 9).

Finally, this fellow calculated a failure pressure for the flattened threads that was much higher than the 2,500 psi at which the joint failed, using generalized equations found in the "Bolts and Nuts" section of *Machinery's Handbook*. Therefore, in his opinion, the flattened threads were irrelevant, and our 2,500-psi calculation was wrong, even though it agreed with the failure pressure. We noted that a recent textbook referencing these same equations warns that they are not valid if the thread geometry gets too far away from the ASME B1.1 standard to which such threads are built. This warning is not in the handbook. His calculations were not valid in this situation because the threads were completely out of spec.

AND THE UPSHOT?

This case settled to our client's satisfaction just before trial, but it seems ridiculous to us that a seriously injured plaintiff had to wait two extra years before a reasonable settlement offer was made. Junk science mouthed by hired guns may make economic sense in some quarters, but fortunately, firms like ours don't buy it. We prefer to use objective, supportable science to do a thorough, accurate job. ■

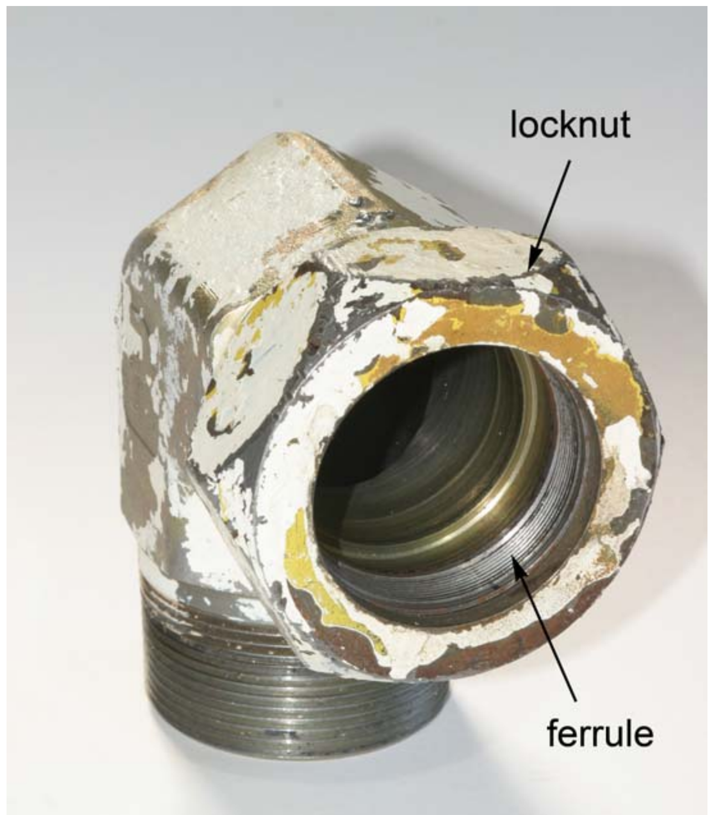


Exhibit 9 – The ferrule installed in the elbow.

ENGINEERING CONFIRMATION

Those of you who want to see the calculation that the joint failed at 2,500 psi may call us or email us at accident.analysis@verizon.net . We have instead used the facing page to list some of the more interesting topics we've covered in newsletters over the years.